DSMS and Huygens

Les Deutsch

IND Architecture and Strategic Planning Office

Bob Preston

IND Chief Scientist

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DSMS and Huygens
Agenda

Les Deutsch

- Background of Huygens mission
- DSMS Roles in the Huygens mission
- The Huygens relay radio anomaly

Bob Preston

- Detecting the Huygens' radio signal on the Earth to measure Titan winds

DSMS and Huygens Background

- The Huygens probe carried by Cassini descended to the surface of Titan on January 14
- Images, physical measurements, and radio science was gathered during the descent into the atmosphere
- Huygens survived to land on the surface, and science data were gathered until Cassini passed Titan
- Cassini/Huygens was a joint NASA/ESA mission
- ESA built the Huygens spacecraft and both ends of the relay radio for the one-way telemetry link
- This link was tested on the ground before launch – but the kinds of signal dynamics expected in the real mission could not be realistically reproduced
- It was discovered in a DSN/Cassini test in 2000 that the link failed under dynamic conditions typical of the planned mission

QuickTimeô and a
Video decompressor
are needed to see this picture.

DSMS and Huygens
Huygens Telecommunications System

Instruments → Frame Assembly → Reed-Solomon Encoder → Convolutional Encoder → Transmitters

Huygens

Receivers → DTTL → Viterbi Decoder → Frame Synchronizer → Data System and Telecom

Cassini PSA

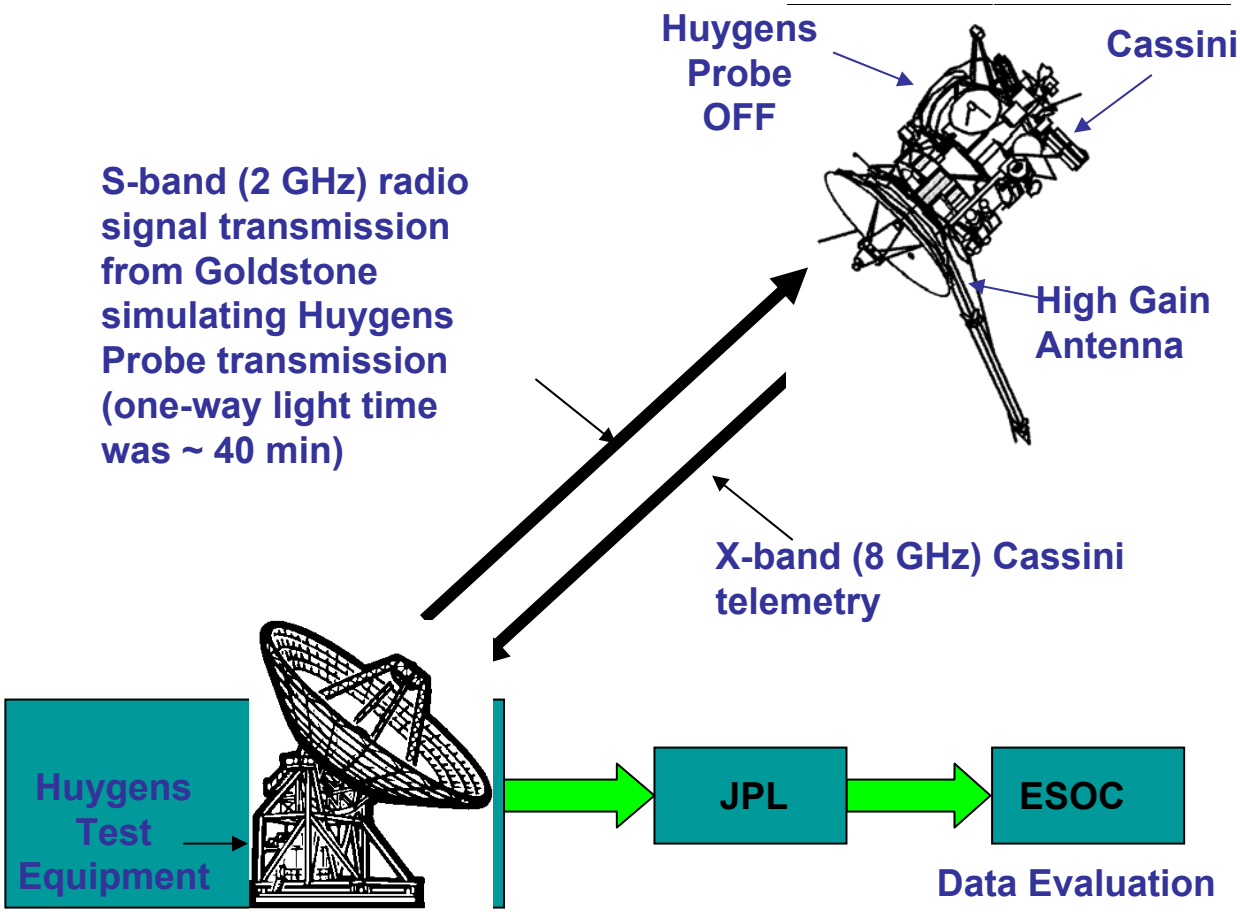
DSN → Reed-Solomon Decoder → Huygens Scientists

ESOC

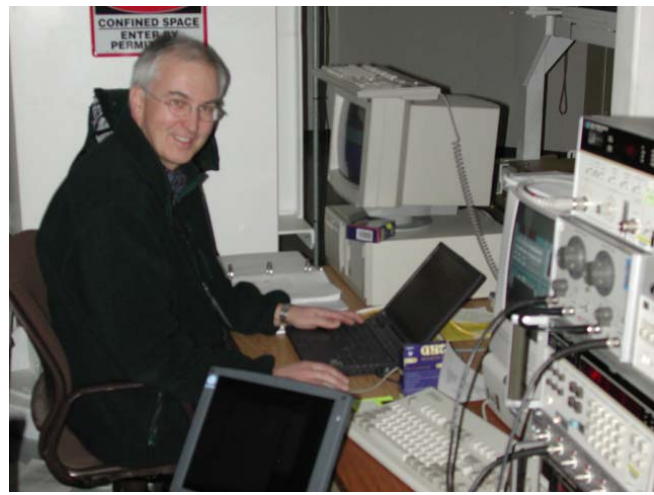
DSMS and Huygens
The DSMS Roles

- All communications between Cassini and Earth are via the DSN
  - The DSN supported all Cassini trajectory maneuvers, bringing it to the correct point for releasing Huygens
  - The DSN carried the probe data, already deposited on board Cassini, bask to Earth
- The DSN was used to discover and characterize the Huygens communications anomaly
- DSMS provided substantial expertise to the Huygens Recovery Task Force (HRTF), the joint NASA/ESA team that redesigned the Huygens mission to mitigate the anomaly
  - I was a co-lead of this team, along with Kai Clausen of ESTEC
  - Many engineers from the DSMS Technology Program participated in the HRTF, resulting in a thorough understanding of the anomaly and the creations of models to predict communication behavior
- DSMS provided equipment that was used to observe Huygens from Earth-based radio telescopes,

DSMS and Huygens Probe Relay Test - Discovering the Problem

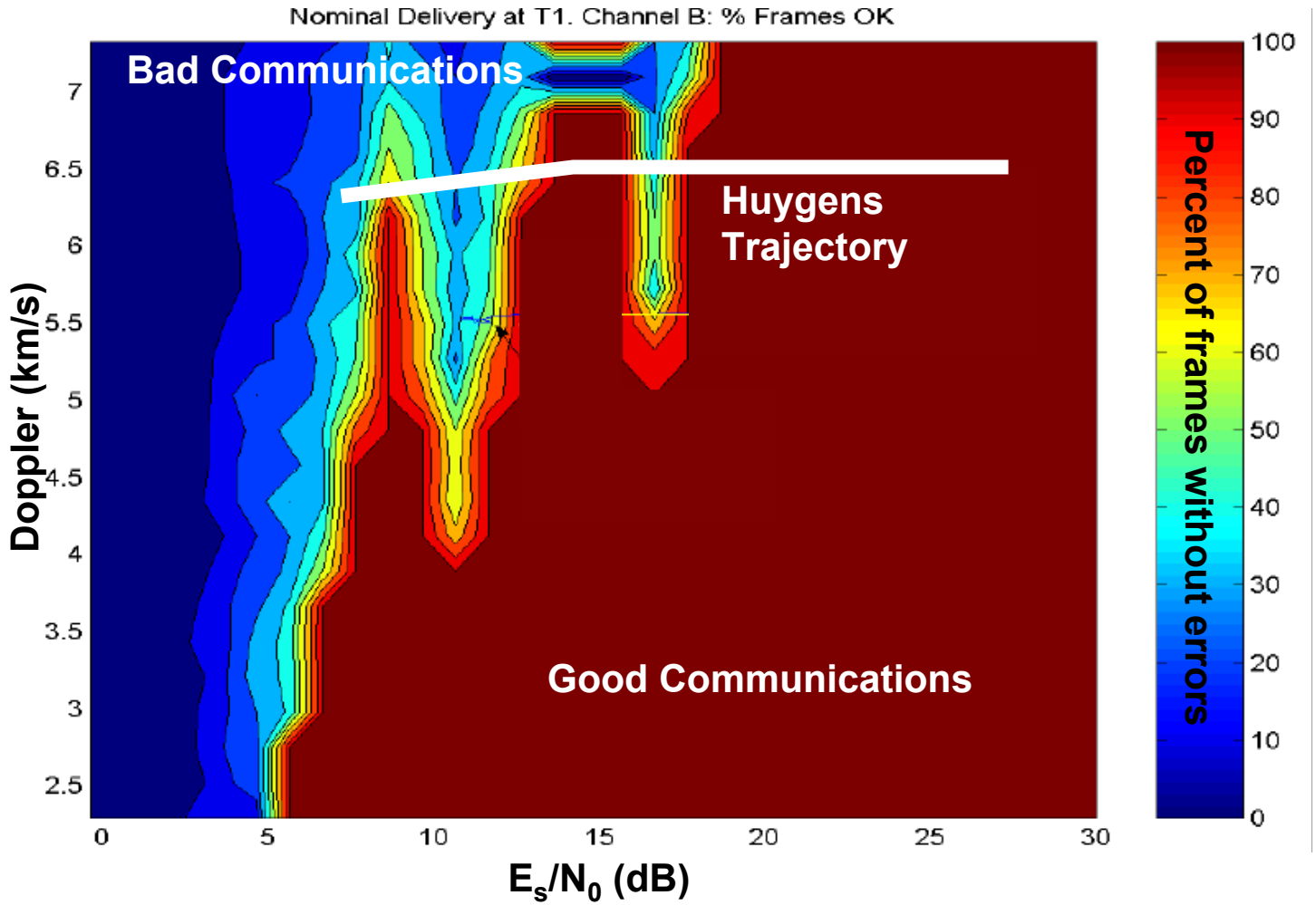


DSS 24



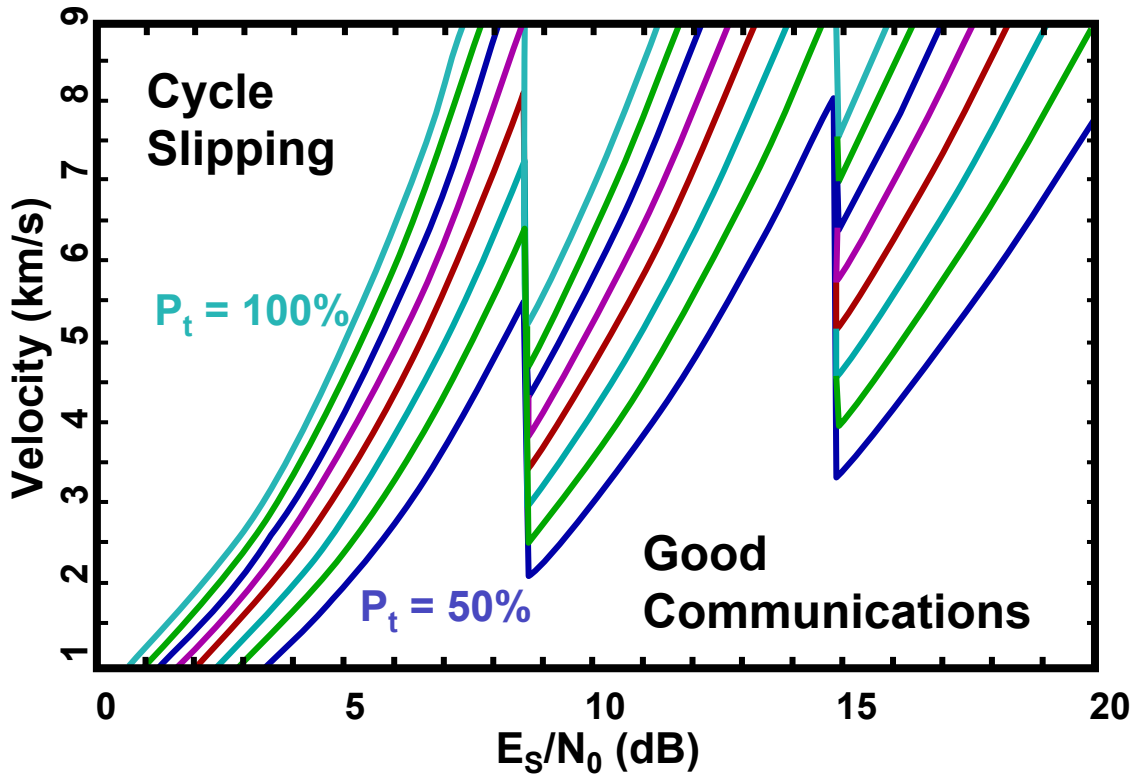
Boris Smeds and Test Equipment

DSMS and Huygens Test Results



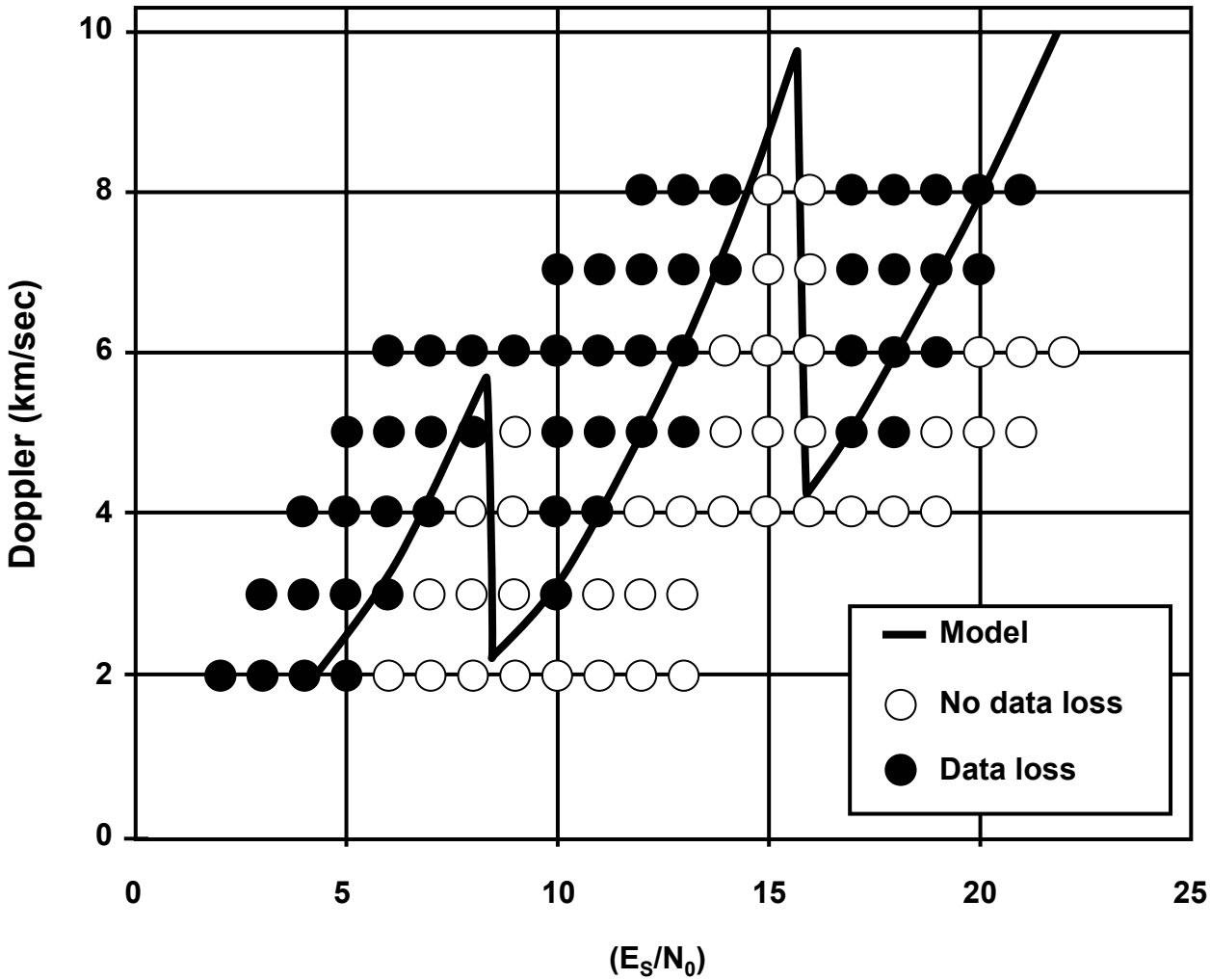
DSMS and Huygens
Modeling the Failure Mechanism

- A complete model of the relay system was developed including
  - Symbol loop dynamics as a function of bit transition probability
  - Convolutional decoding
  - Frame synchronization
  - Reed-Solomon decoding
- Symbol cycle slips were generated with a period that is a function of E_b/N_0, Δf, and P_t
- Fingers are caused by AGC function
- Analysis showed the anomaly was caused by improper bandwidths chosen for the symbol loop
- Unfortunately, all PSA parameters were hard-coded and could not be changed in flight



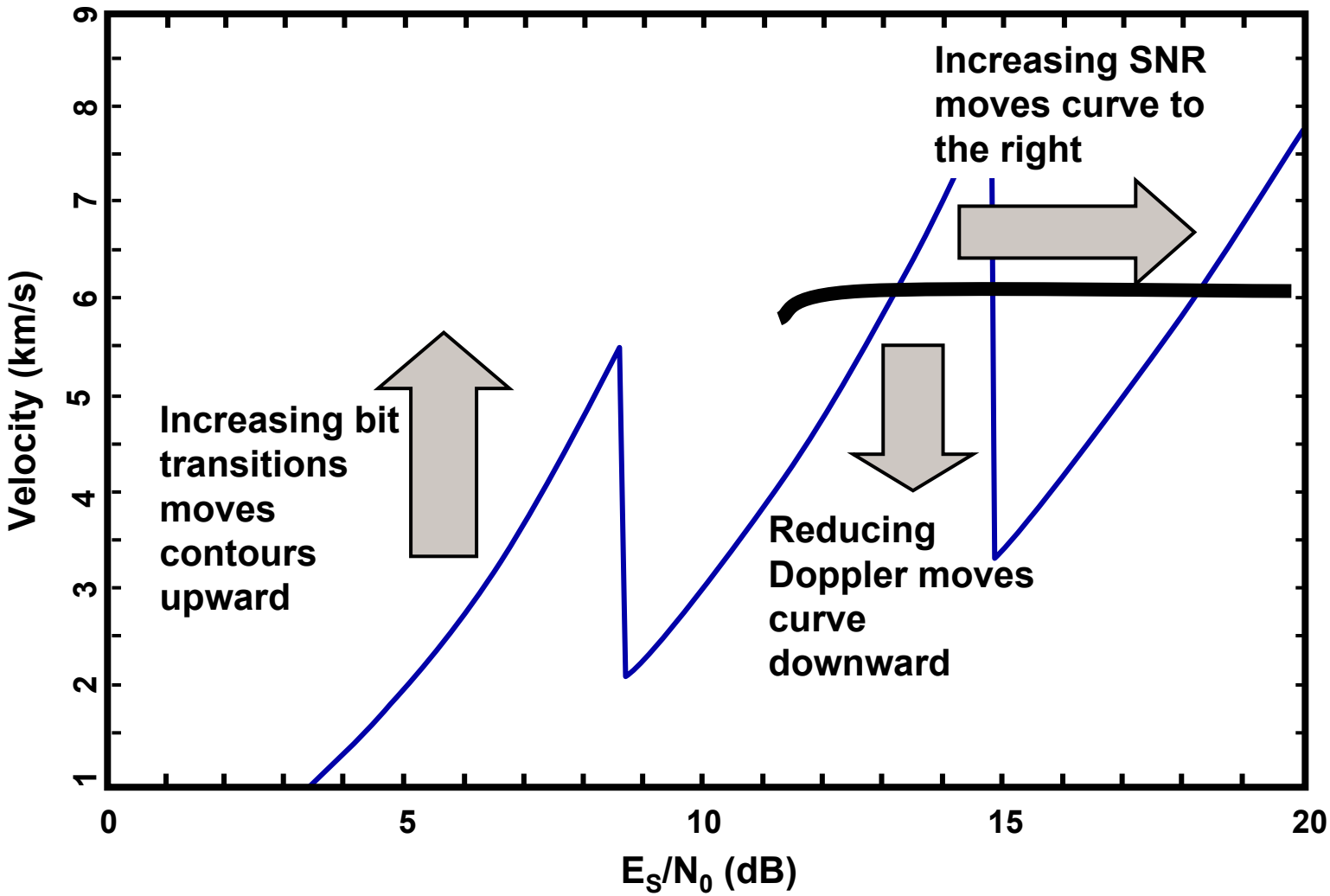
DSMS and Huygens
Verifying the Model

- Additional DSN tests were run to verify and calibrate the model
- Results were excellent



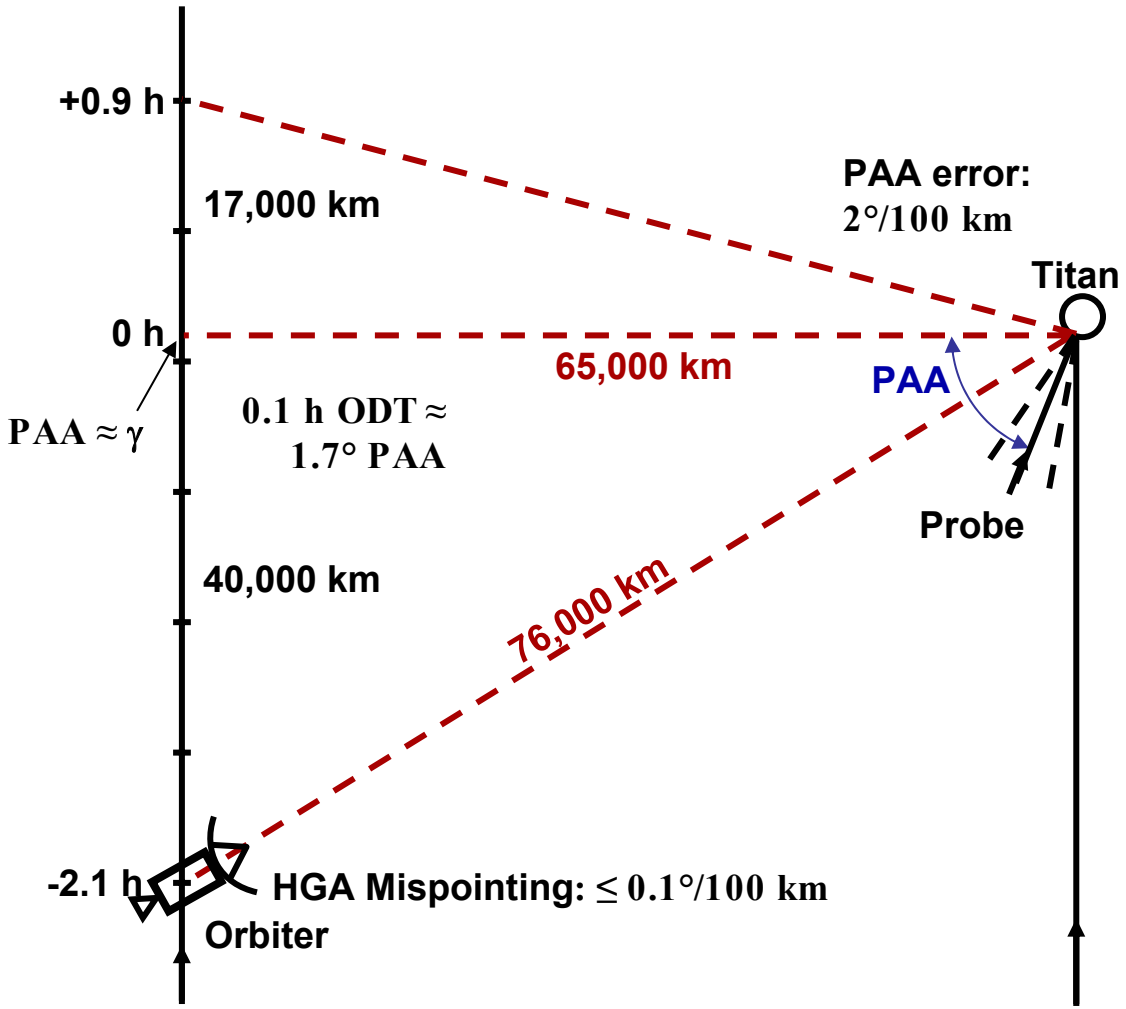
DSMS and Huygens
Ways to Improve Data Return

Varying the critical parameters "moves" the probe curve with respect to the contours - resulting in more good data returned to Earth



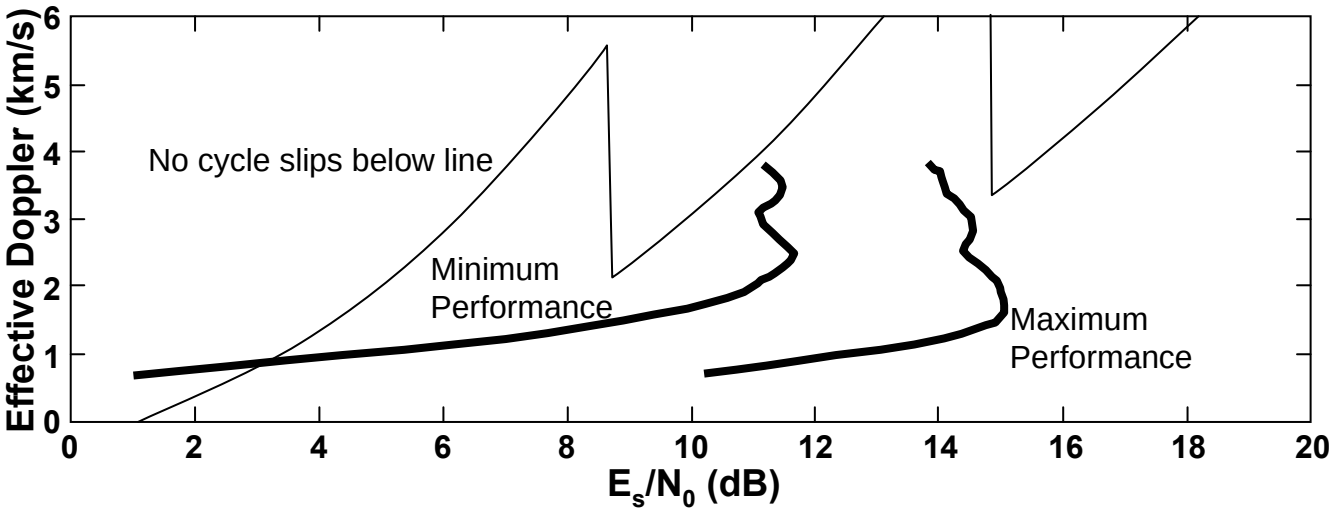
DSMS and Huygens
A New Retrograde Flyby Saves the Day

- The trick now was to find a high altitude flyby that uses minimal fuel (~150 m/s for simple altitude increase)
- JPL navigators came up with the idea of flying by the opposite side (retrograde) of Titan
- This uses Titan's gravity to help more with Cassini maneuvers
- New trajectory minimized additional propellant needs (~100 m/s)
- There is actually a class of these trajectories with one ultimately chosen by the Project



DSMS and Huygens
Recommended Solution

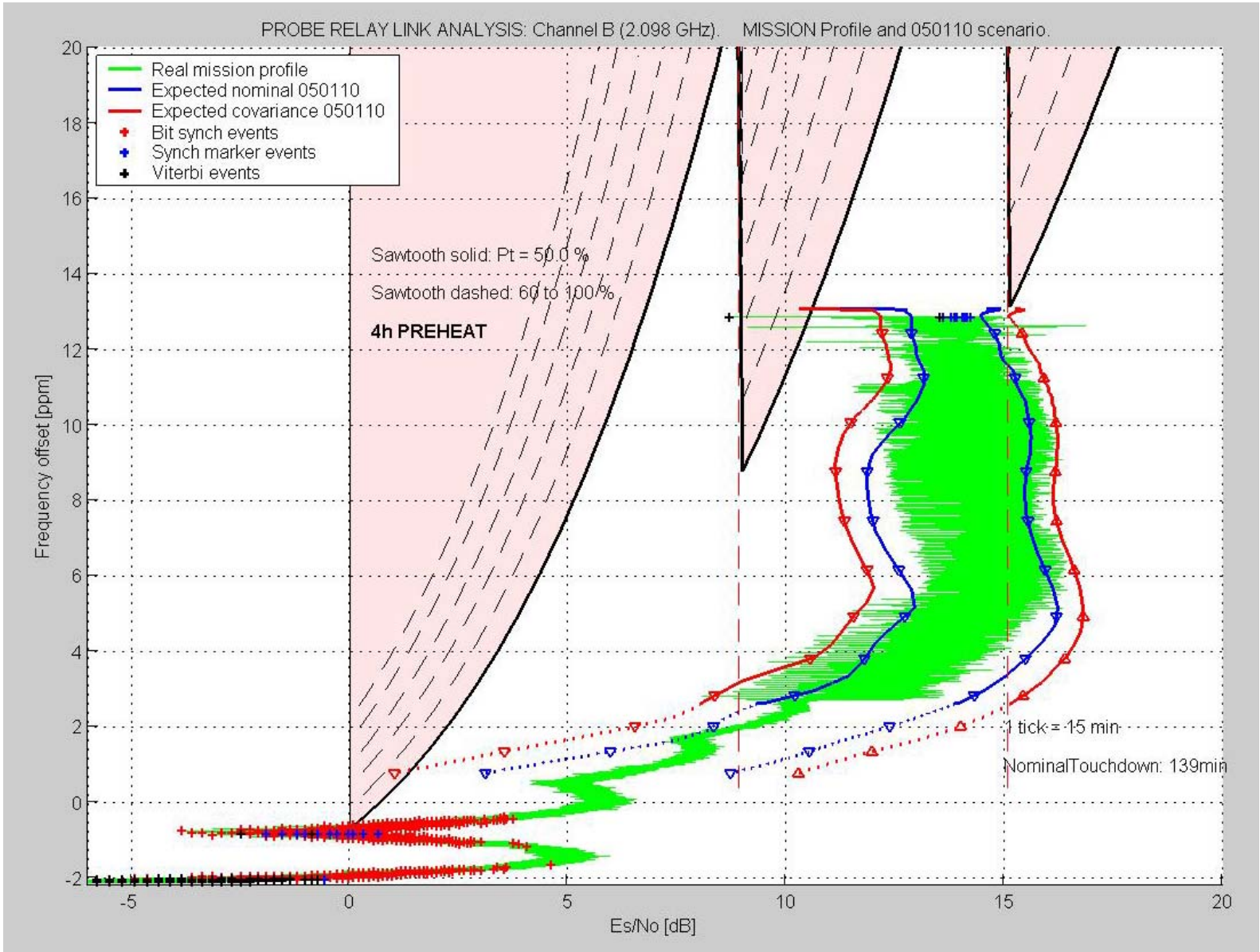
- In addition to the new trajectory, the team recommended preheating of the Huygens oscillators
  - Huygens batteries enabled four hours before start of transmission
- The team developed several point designs that showed possible solutions to the anomaly
  - Each of these would return close to 100% of the data with margin
- The trick here was that communication performance had to be bounded both from above and below
  - Too much margin is bad!
- Our experience with Galileo (operating 0.5 dB from theoretical) helped



DSMS and Huygens
DSN Support of Probe Data Playback

- Cassini turned its HGA to receive probe data during actual descent
  - No visibility during actual probe mission was possible
- After turning to Earth, Cassini commenced playing the probe data to the DSN
  - Eight full copies were sent, over all DSN complexes
  - Provided redundancy for the data playback
  - Provided resiliency in case of any two 70m failures
- The DSN performed flawlessly
- One of the two communications channels on Huygens failed (no data)
  - This was a known risk (this is why there were two channels!)
  - All housekeeping data was redundant on the two channelsMost scientists planned their data campaign to satisfy their main goals with either single channel

DSMS and Huygens
Reconstructed Real Finger Diagram



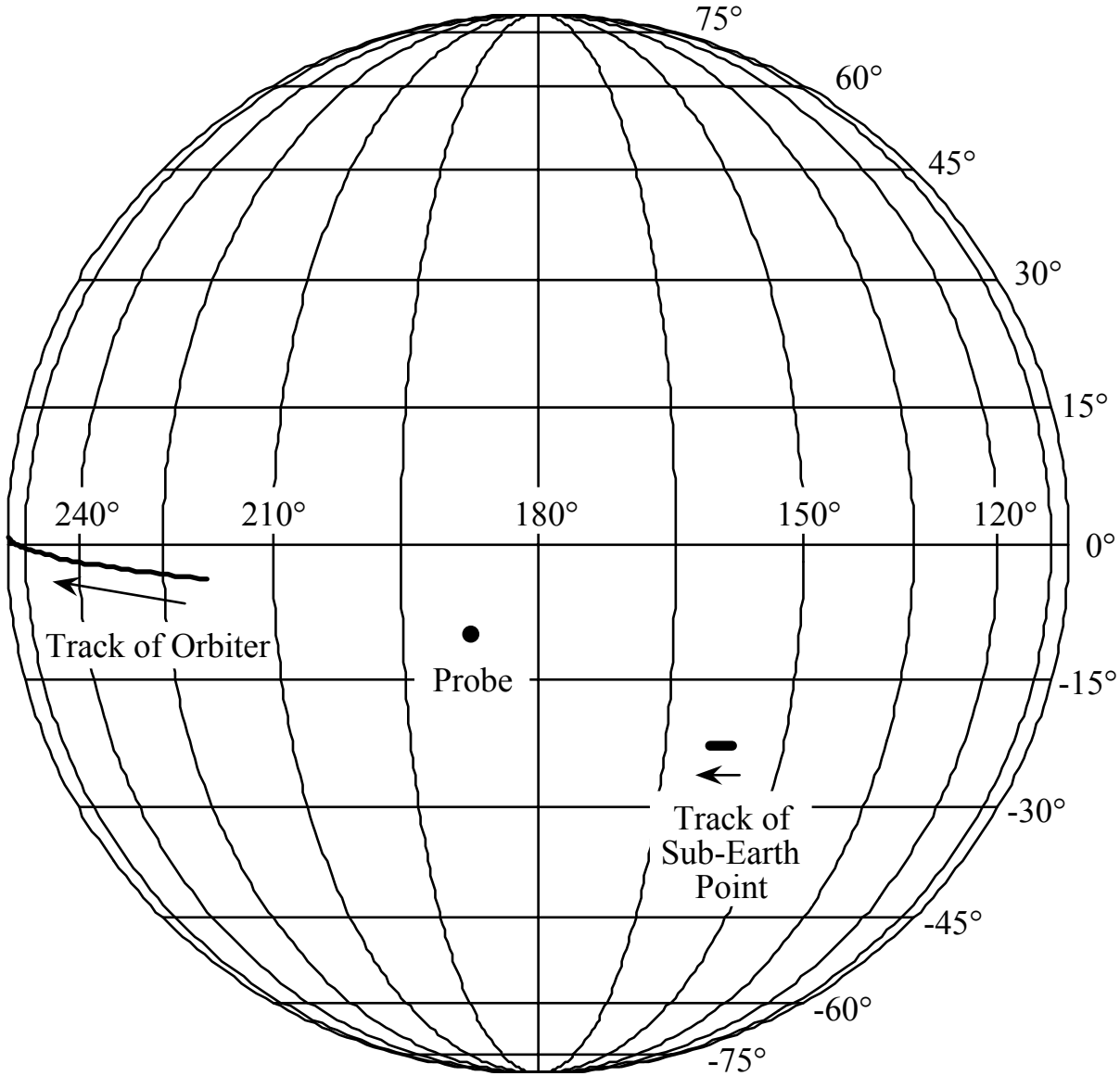
DSMS and Huygens
Measuring Winds on Titan

- The study of winds in the Titan atmosphere is one of the scientific goals of the Huygens mission
- Wind determination is based on Doppler shift measurements of the S-band radio signal transmitted from the Huygens Probe
- Different components of the wind were to be determined from the Doppler signatures between the probe and the orbiter and the probe and the Earth
  - Unfortunately, there was a failure of the probe-orbiter channel on which Doppler was to be measured
  - So Probe-Earth Doppler data (gathered by JPL team) will provide the only precision measurement of Titan's wind
  - Ground-based VLBI measurements of the probe (led by European team) will provide a history of the sky position of the probe, and some constraint on the missing wind component
- A JPL team performed a similar experiment with the Galileo Probe, using Earth-based detection of the probe signal to determine Jupiter's winds

DSMS and Huygens
Detection of Huygens Signal on Earth

- The Huygens signal was not designed for Earth-based detection
- Earth-based detection is very marginal, and relies on:
  - The most sensitive ground-based radio telescopes
  - Low levels of atmospheric turbulence and resultant swinging of the probe on its parachute
  - No big wind changes over the detection period (typically 1 to 10 sec)
- Detection should be possible most or all of the time using just the residual carrier signal
- The original plan was to improve the SNR by using data bits as relayed to orbiter to take modulated phase transitions out of data
  - However, this is the telemetry channel that failed

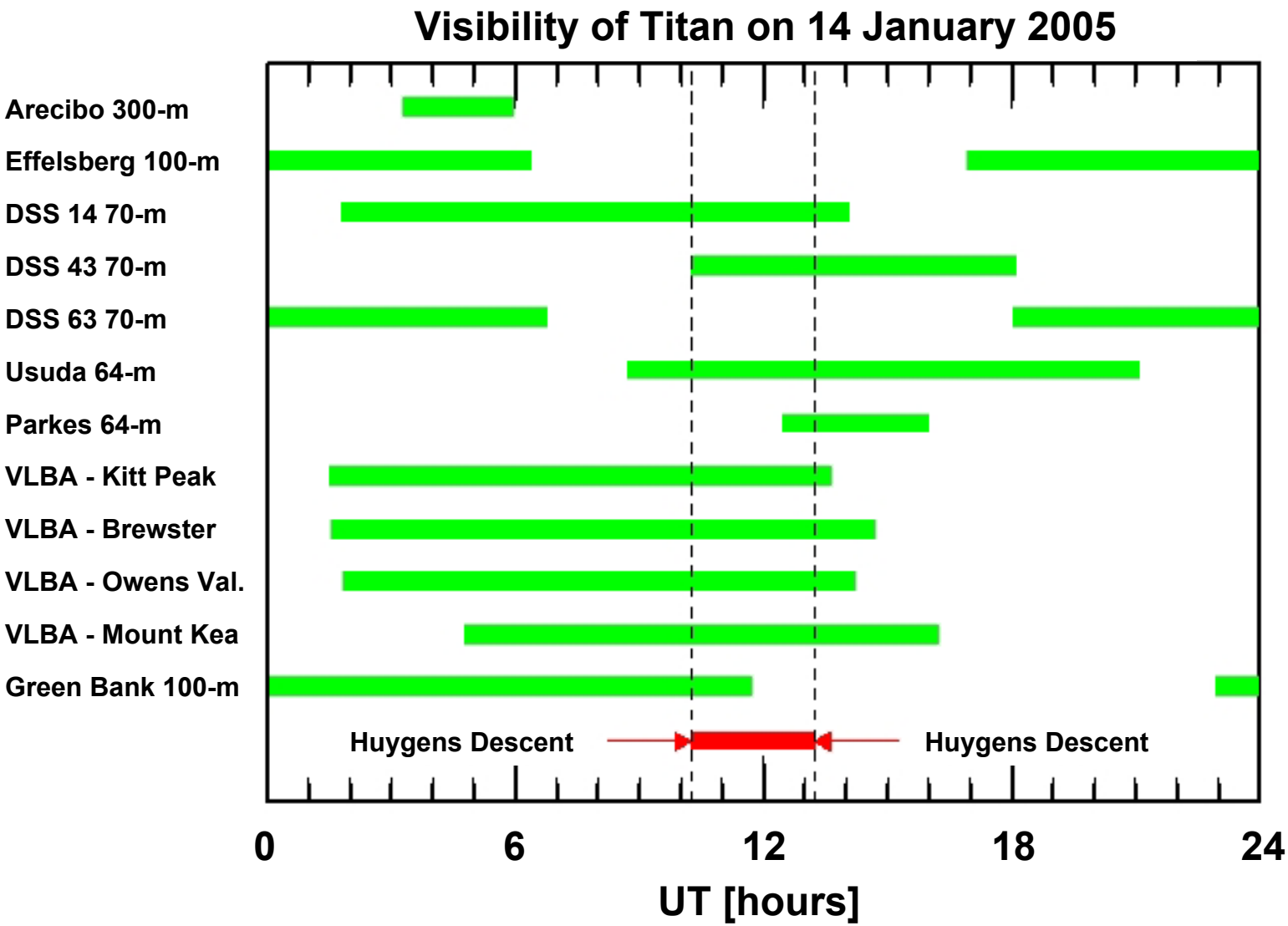
DSMS and Huygens
Huygens Probe Geometry on Titan



DSMS and Huygens

View of Earth from Huygens at Titan at Start of Descent

DSMS and Huygens
Radio Telescope View Periods



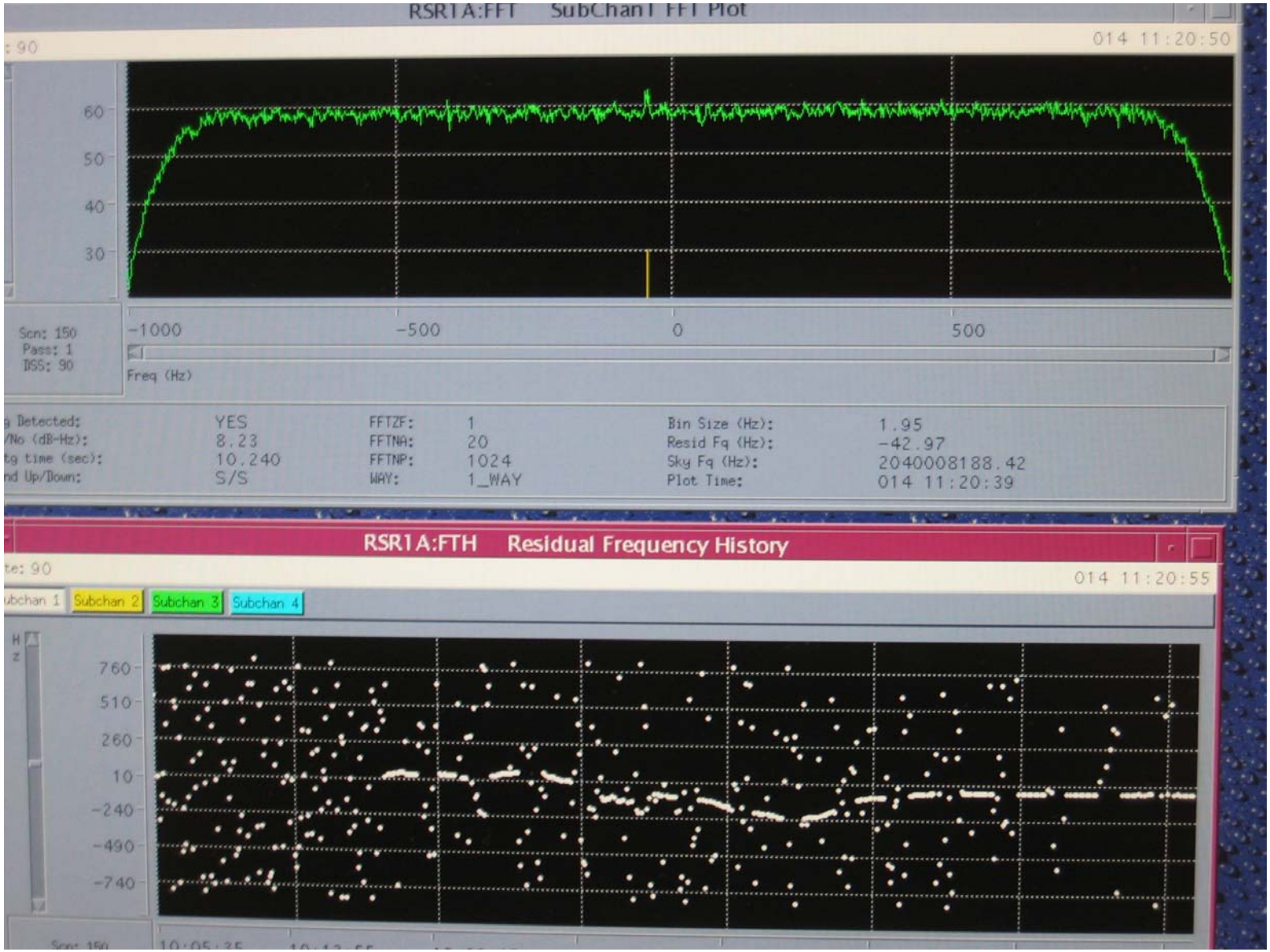
DSMS and Huygens
JPL Team Members

- Aseel Anabtawi
- Sami Asmar
- Jim Border
- Bill Folkner
- Sue Finley
- Garth Franklin
- Jacob Gorelik
- Doug Johnston
- Andre Jongeling
- Viktor Kerzhanovich
- Steve Lowe
- Bob Preston

The JPL team is collaborating with ESA's Huygens Doppler Wind Experiment Team led by Mike Bird

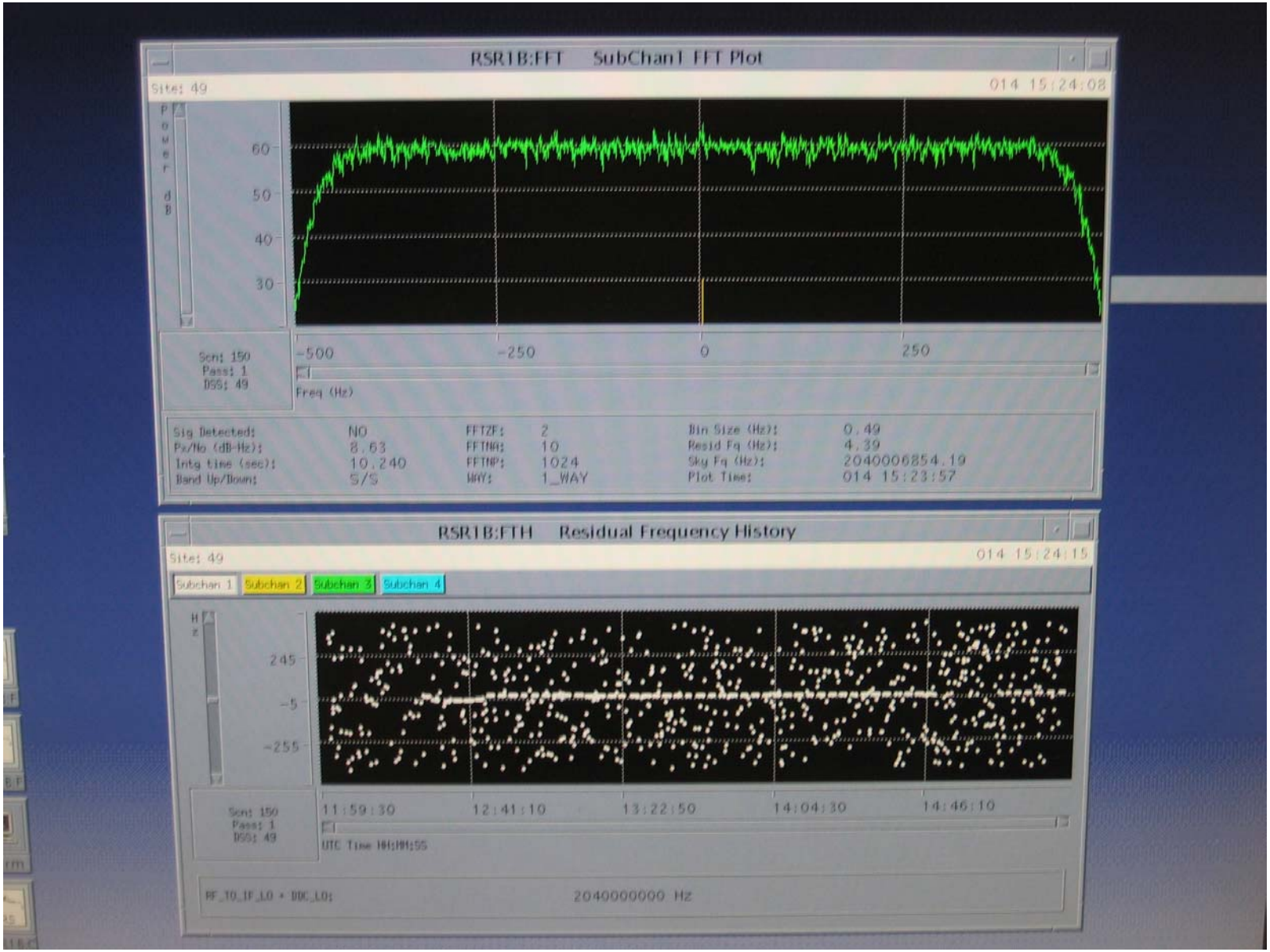
DSMS and Huygens

Huygens Realtime Detection at the Green Bank Telescope

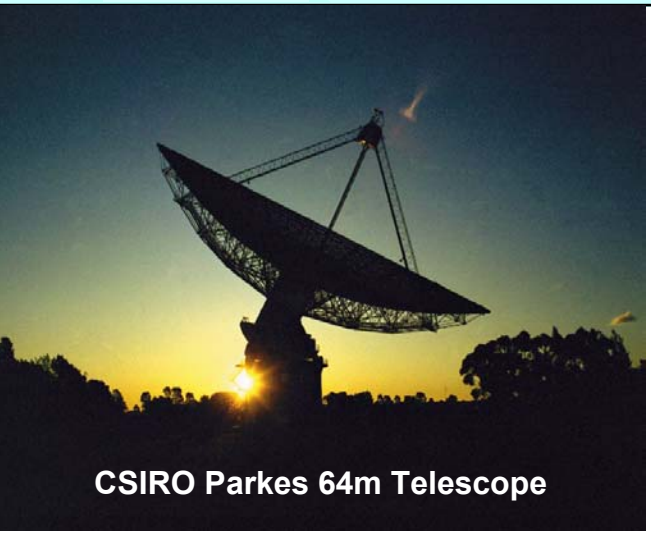


DSMS and Huygens

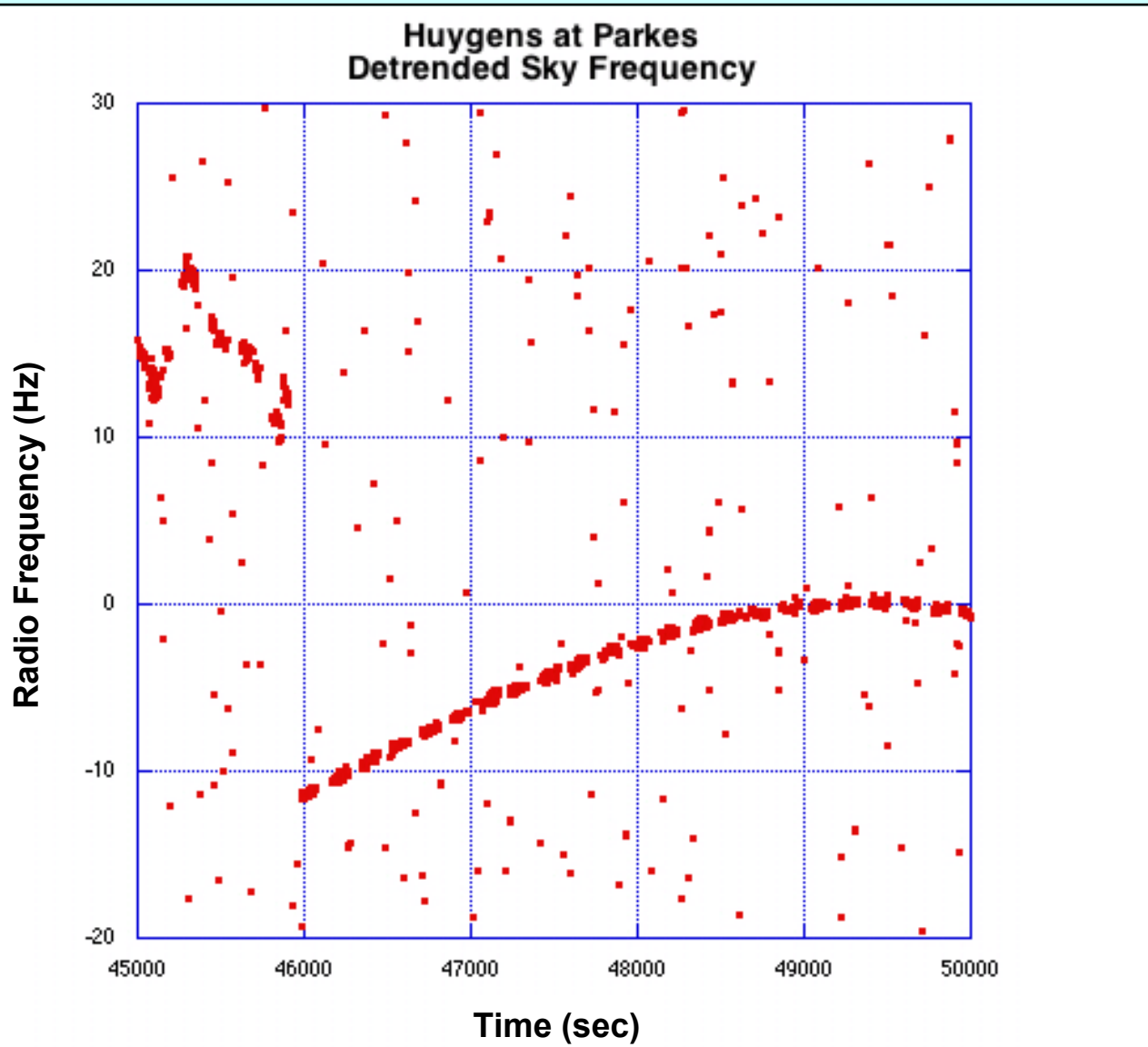
Huygens Realtime Detection at the Parkes Telescope



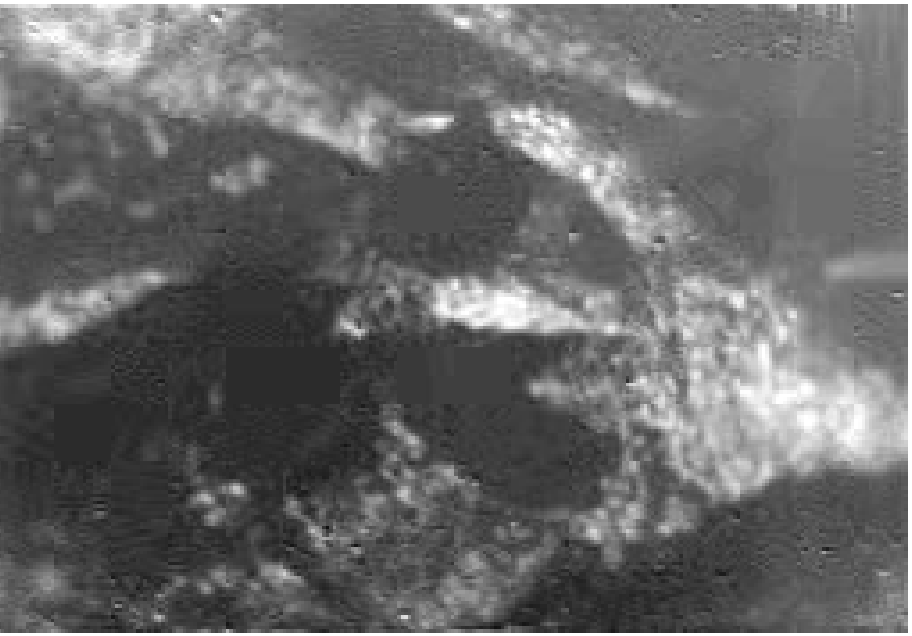
DSMS and Huygens Landing (Parkes Telescope)

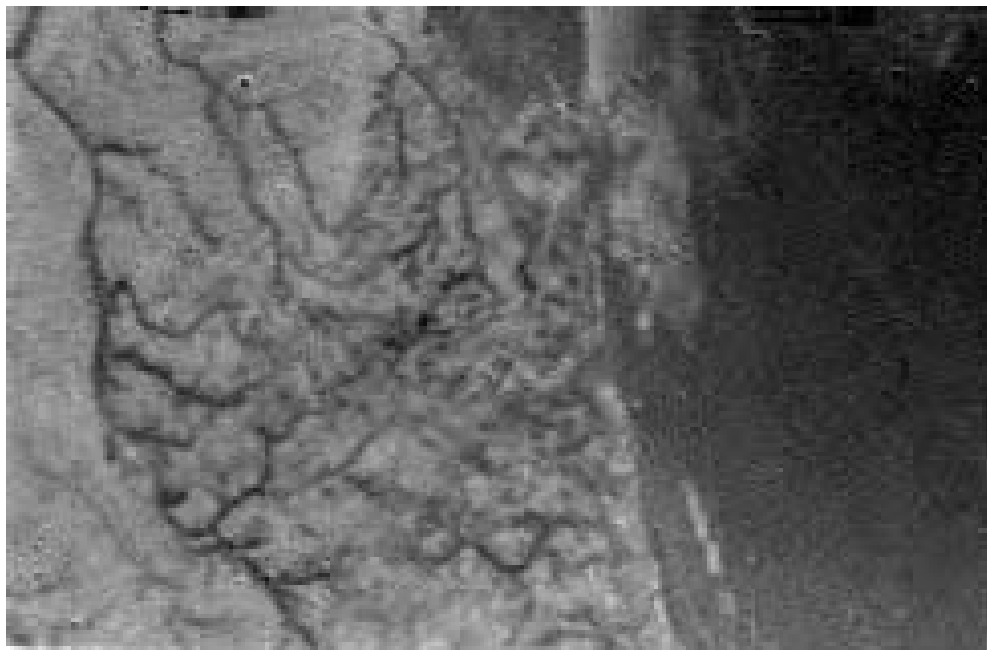


CSIRO Parkes 64m Telescope



DSMS and Huygens
Some Early Titan Images





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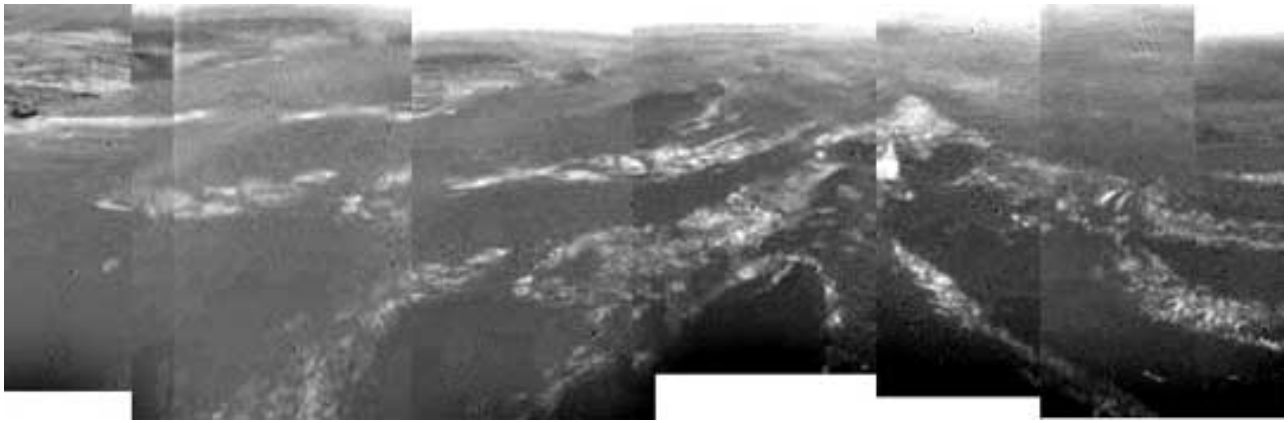
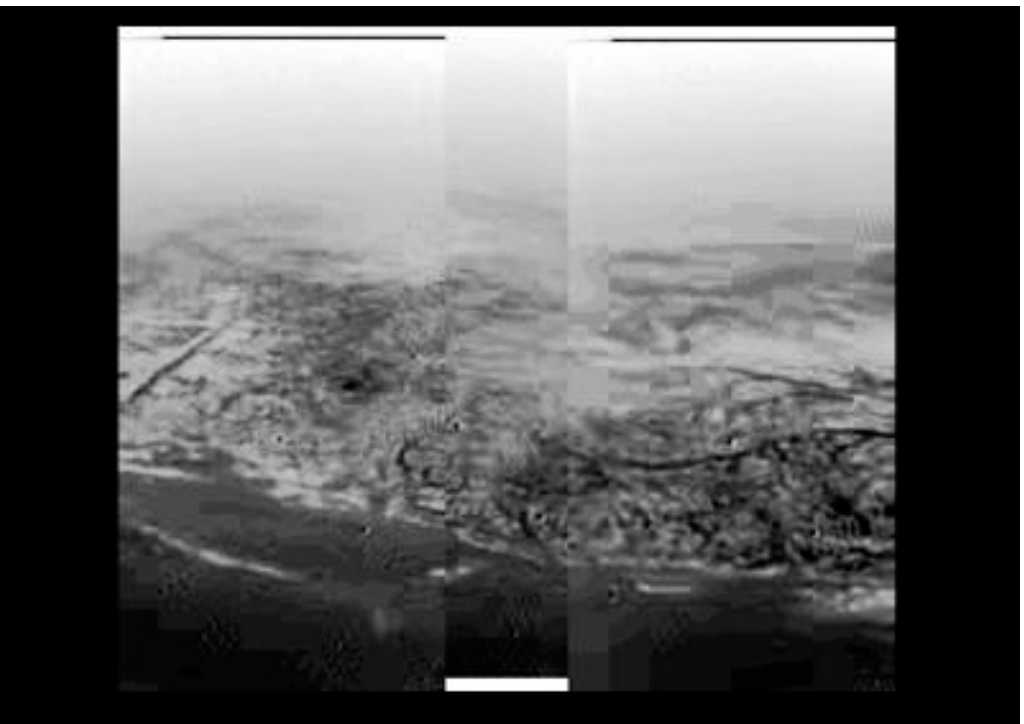
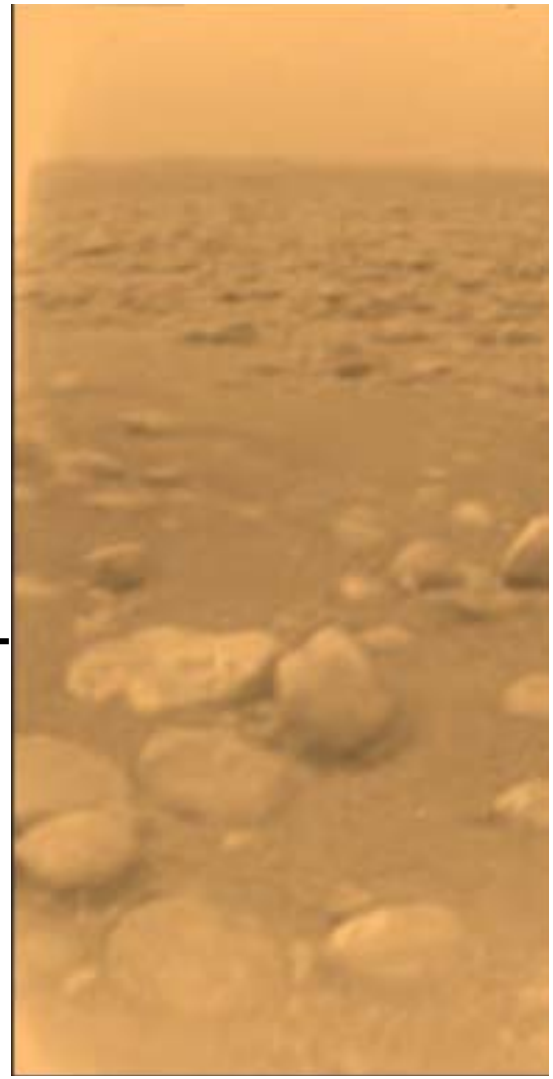




15cm



DSMS and Huygens "Take Aways"

- The DSN continues to operate in a reliable manner and is a partner in the success of its user missions
- Huygens is yet another example of the DSMS Technology Program helping to rescue a mission
  - Their expertise is world class and world unique
- The ability of the DSN to do special observations should be maintained
  - This was critical to discovering and characterizing the problem
- Large effective apertures can aid missions through science-like observations
  - Green Bank and Parkes provided essential insight into the status of Huygens
  - We need to maintain close relationships with the radio astronomy community